The Impact of Parcel Structure on the Efficiency of Finnish Dairy Farms

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In Finland, expanding dairy farms often face the problem of additional fields being geographically distant and only available as small parcels. We develop a stochastic production frontier model to estimate the technical efficiency of Finnish dairy farms and simulate the effect of parcel distance and parcel size on the efficiency of an average farm for 2000 through 2009. The overall development of technical efficiency is positive during the study period but increases in distance and decreases in parcel size both significantly reduce farm efficiency. Therefore, efforts to improve the parcel structure are justified.

Key Words: milk production, parcel structure, stochastic frontier, technical efficiency

Land is a fundamental input in agricultural production. Therefore, the availability and parcel structure of agricultural land are essential factors in investment decisions and efforts to expand operations. Expansion, in turn, is a means by which farmers try to improve their productivity and productivity growth. Productivity growth is also one of the main objectives of the Common Agricultural Policy (CAP) in the European Union (EU) (Meester 2011).

In Finland, agricultural areas occupy a smaller proportion of the total land area (9 percent) than in most European countries and the area occupied by lakes and water courses is large (11 percent), resulting in small, often irregularly shaped areas of agricultural land. Also, almost all of Finland's agricultural land is located above a latitude of 60 degrees north. The country is divided into support areas to offset profitability differences between more and less favorable agricultural regions. The AB region represents southernmost Finland, which is more suitable for agriculture. Regions C1, C2, C3, and C4 represent progressively northerly areas in which growing seasons are shorter and temperature sums are lower than in the south.

The structure of the Finnish dairy sector has changed dramatically in recent years and will continue to change in the near future. Milk production is concentrating in larger, more capital-intensive units to improve the competitiveness of the dairy sector. The number of dairy farms is likely to decrease from about 9,000 in 2012 to less than 6,000 by 2020 (MTT 2014), and this concentration has had a major effect on the demand for land and on land prices (Pyykkönen 2006).

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In Finland, a farmer has to apply for an environmental permit to expand animal production. One of the requirements for the permit is a minimum area of land that must be available for spreading manure. Currently, the required area is 0.77 hectares per cow, 0.29 hectares per heifer (12–24 months of age), 0.22 hectares per female calf 6–12 months of age, and 0.09 hectares per female calf less than 6 months of age. Owning or leasing the area is not necessary; it is possible to meet the requirement through manure-spreading contracts with other farmers (Environmental Administration of Finland 2000, Finnish Ministry of the Environment 2010). In environmental permits granted in 2009 through 2012, the dairy expansions often were large, doubling or tripling an operation's milk-production capacity. Consequently, the availability and price of land restricted expansion in some cases. Clearing of arable land also has increased in areas in which milk production is most concentrated.

Milk production is characterized by a close link to arable farm land, not only because of manure requirements but also due to a need to produce feed. Farms usually produce most of their own feed or buy it locally. Ruminants need rough feeds in their diets, and self-sufficiency in provision of roughage is typically a minimum requirement for milk production (Sipiläinen 2007). A single farm in Finland usually operates a large number of small land parcels that are located some distance from the primary farm compound (Myyrä and Pietola 2002). In addition, because of comparative advantages, Finnish dairy production is concentrated in northern Finland, which has the greatest amount of fragmentation of parcels (support areas C1 and C2 in particular).

Del Corral, Perez, and Roibas (2011) summarized negative effects associated with parcel distance, which induces a lack of labor productivity as well as higher transport costs for inputs and outputs. Since a single cow annually requires close to ten tons of roughage feed (wet matter) and produces 24 cubic meters of manure, parcel distance plays an important role in the logistics of a dairy farm. Moreover, high-quality silage requires good timing in terms of harvesting, which is made more challenging when a bigger share of resources must be spent transporting the harvest.

Another component of land fragmentation is parcel size. Compared with large rectangular fields, small parcels make less efficient use of machinery (Buller and Bruning 1979) or can entirely prevent the use of highly efficient modern technologies. Small parcels also may have a relatively large share of edges overshadowed by adjoining woods or drainage problems that affect yields, both of which reduce the economic performance of the farm. Indeed, Myyrä and Pietola (2002) suggested that it is likely that the smallest parcels are eventually left idle or kept as set-asides even on farms that specialize in cattle rearing or dairying.

Currently, one-third of all Finnish fields are cultivated as leases-outs, often under relatively short contracts that do not motivate the lessee to invest in renovation or drainage to improve the usability or the size of individual parcels. A farmer looking to expand often requires every available parcel in the area, even the smallest ones. Thus, ongoing structural development increases the farm's size but parcel size remains practically stagnant (Myyrä and Pietola 2002). Industry analysts have wondered, therefore, whether expanding an operation's size results in greater productivity. Benefits that arise from the increase in farm size may not be entirely realized due to growing fragmentation (Hiironen 2012). However, this question has not been analyzed empirically.

We estimate the technical efficiency of Finnish dairy farms by focusing on the impact of parcel structure—how much of potential efficiency is lost because of small parcel sizes and long parcel distances. The connection between land fragmentation and efficiency has been previously studied for crop production in China (Wu, Liu, and Davis 2005, Tan et al. 2010), Bangladesh (Rahman and Rahman 2008), and India (Manjunatha et al. 2013). Del Corral, Perez, and Roibas (2011) analyzed the impact of land fragmentation on productivity and profits for Spanish dairy farms. However, there are many differences in how dairy cows are fed and manure is handled in Spain versus the northernmost countries of Europe so the impacts of land fragmentation may also differ. Moreover, Del Corral, Perez, and Roibas (2011) measured land fragmentation by number of parcels but ignored area and distance. The empirical data used in our study allow us to analyze the effects of size and distance on efficiency.

Material and Methods

Stochastic Production Frontier Model

The objective of producers can be as simple as obtaining maximum outputs from given inputs or minimizing input use in production of given outputs. Producers operating on their production frontiers are labeled as technically efficient and producers operating at less than that level as technically inefficient (Kumbhakar and Lowell 2000). The stochastic production frontier model that appears in the current literature was originally developed by Aigner, Lovell, and Schmidt (1977). Several improvements have since been made. For example, Battese and Coelli (1992, 1995) introduced a production frontier model for panel data. Following Battese and Coelli (1995), we can express the stochastic production frontier as

(1) $$Y_{it} = \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} - u_{it}$$

where Y_{it} is production and $\mathbf{X}_{it}$ is a vector of production inputs (see Table 1). $\boldsymbol{\beta}'$ is a vector of unknown parameters to be estimated, and i and t denote a farm and a time period, respectively, so that the efficiency scores can vary from year to year. In the model, v_{it} is an error term that is assumed to be identically distributed (N(0, σ_v^2)) and distributed independently of u_{it}, which is a vector of non-negative random variables associated with technical inefficiency of production. The error term v_{it} captures statistical noise and other stochastic shocks. The one-sided disturbance term u_{it} represents deviation of each firm from the technically efficient frontier, factors that are under the control of decision-makers, whereas the two-sided error term v_{it} represents uncontrollable factors that indicate whether the frontier can vary randomly across firms. We assume that u_{it} is independently distributed such that u_{it} is obtained by truncation (at zero) of the normal distribution with mean $\boldsymbol{\delta}'\mathbf{z}_{it}$ and variance σ_v^2. In the model, $\mathbf{z}_{it}$ is a vector of farm-specific inefficiency variables that may change over time and $\boldsymbol{\delta}'$ is a vector of unknown coefficients. In the stochastic frontier model, u_{it} can be specified as

(2) $$u_{it} = \boldsymbol{\delta}'\mathbf{z}_{it} + \mathbf{w}_{it}$$

where $\mathbf{z}_{it}$ is a farm- and time-specific vector of values that explain inefficiency, $\boldsymbol{\delta}'$ is a vector of parameters to be estimated, and $\mathbf{w}_{it}$ is obtained by truncation of the normal distribution with zero mean and variance σ_v^2 such that the point of truncation is $-\boldsymbol{\delta}'\mathbf{z}_{it}$ (Battese and Coelli 1995).

The technical efficiency (TE) describes the ratio of observed output to maximum feasible output, and TE of production is defined as

$$\mathbf{TE}_{it} = \exp(-u_{it}) = \exp(-\boldsymbol{\delta}'\mathbf{z}_{it} - \mathbf{w}_{it}). \tag{3}$$

Because the observed output is always less than or equal to the maximum output, the TE index is restricted between 0 and 1. TE achieves its upper bound when a farm produces the maximum technologically feasible output given the input quantities.

Empirical Data and Model

The empirical results are based on a panel data set of specialized Finnish dairy farms in the European Commission's Farm Accountancy Data Network (FADN). Farms were designated as dairy farms when more than two-thirds of their standard output originated from milk production. The research period covers the years 2000 through 2009, and the data form an unbalanced panel with 568 individuals and 3,329 observations.

Production frontiers of both the translog (e.g., Byma and Tauer 2010, Alvarez, Del Corral, and Tauer 2012) and Cobb-Douglas type (e.g., Cabrera, Solis, and Del Corral 2010) have been applied to milk production. The translog function is more flexible but, with our unbalanced panel data, it suffers from monotonicity violations (e.g., Chambers 1988). These two function types produce equally significant parameter estimates, the values of which are very close to each other. Consequently, the key results are robust to the choice of model. Our empirical analysis is based on a Cobb-Douglas-type production function that expresses both outputs and inputs in logarithmic form. Time dummy variables were included in the production function as an indicator of neutral technical change (Baltagi and Griffin 1988). In addition, regional dummy variables in the model capture the effect of spatial differences in the production environment. Likelihood ratio tests indicated that the presence of both dummy variables improved the fit of the model ($p < 0.001$). Their inclusion in the production function represents an assumption that they directly affect the shape of the frontier but not the distance from the frontier. In this case, TE is net of effects related to technical change and the production environment. This assumption is in line with the results of Sipiläinen and Ryhänen (2005), which estimated a stochastic production frontier for Finnish production of grass silage with various model specifications.

Since the farms in our data set specialized in milk production, we followed the method introduced by Alvarez, Del Corral, and Tauer (2012) and converted all non-milk outputs to milk liter-equivalents by dividing the revenue from the items by the price of milk. The average producer price of milk was used in the conversion. The inputs are capital stock, land area, labor hours, and cost of materials and supplies. All monetary values are presented with fixed 2010 prices. Market returns were deflated with the producer price index, capital values with the consumer price index, and material costs with the input price index of agriculture, all from Statistics Finland (2013a, 2013b). The producer price of milk was obtained from Tike (2013).

Table 1 presents descriptive statistics for the variables in the frontier model, and Table 2 provides data on arable area, parcel size, and distance for 2000 through 2009. The data for parcel size and distance were obtained from the parcel register maintained by the Finnish Agency for Rural Affairs (MAVI), which collects the information to manage and control area-based CAP supports. The distance from a farm compound to the middle of each parcel was calculated from coordinate information with a Pythagorean equation:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{4}$$

where (x_1, y_1) and (x_2, y_2) are the x and y coordinates of the farm compound and the parcel's middle point, respectively, and D is distance. The coordinates

Table 1. Descriptive Statistics of Production Frontier Model Variables

Variable Description	N	Sum	Mean	Std. Dev.
Total market return, euros	3,329	—	104,054	74,204
Milk output, liters	3,329	—	235,093	170,012
Output, equivalent to milk liters	3,329	—	270,880	194,027
Capital stock, no ag. land area, euros	3,329	—	312,462	294,009
Land area, hectares	3,329	—	55.6	32.7
Labor, hours	3,329	—	5,123	1,892
Cost of materials and supplies, euros	3,329	—	103,303	76,503
Binary variable, region AB	—	598	0.18	—
Binary variable, region C1	—	727	0.22	—
Binary variable, regions C2–C2P	—	1,578	0.47	—
Binary variable, regions C3–C4	—	426	0.13	—

Table 2. Development of Average Arable Area, Parcel Size, and Distance for 2000–2009

	Total Arable Area in Hectares	Parcel Size in Hectares	Weighted Parcel Distance in Meters	Arithmetic Parcel Distance in Meters	Number of Parcels
2000	43.4	2.49	1,937	4,646	20
2001	46.2	2.45	2,028	4,743	21
2002	47.6	2.45	1,931	4,600	22
2003	49.2	2.45	1,811	4,405	23
2004	51.6	2.48	1,898	4,613	23
2005	57.0	2.45	2,030	4,956	26
2006	59.0	2.48	2,100	5,141	26
2007	62.2	2.53	2,155	5,447	27
2008	66.4	2.57	2,321	5,991	28
2009	70.3	2.59	2,326	6,001	30

were from the Finnish Basic Coordinate System (Finland Zone 3), a rectangular plane coordinate system (Ollikainen and Ollikainen 2004). For small distances, the cosine correction for the shape of the globe was not considered necessary.

Weighted distance (average distance of a field hectare) can be used when one needs to describe a parcel structure with a single value (Suomela 1950) and gives more reliable information about a parcel's structure than an average arithmetic distance, which might be disturbed by a single small parcel located at a long distance away. We calculated average parcel distance as farm- and time-specific by multiplying the parcel's size by the mean parcel distance and then dividing that product by the total area of the farm.

In the distance data, some utmost observations were considered to be outliers. A typical outlier was a farm that had two or more separate compounds located a long distance from each other. Another example is a farm that had a completely separate single field parcel far from the farm. This sort of field could be completely cultivated by a contractor and would not necessarily have much to do with the farm's production of roughage or manure logistics. Altogether, 30 of the 568 farms included parcels that were more than 50 kilometers from the primary compound and were excluded from the data.

In the inefficiency model, the average distance to parcels and average size of parcels were supplemented with the squared and crossed values of those variables. Dummy variables were used to capture the effects of the (i) type of production (organic and conventional) and (ii) type of housing for cows (loose housing and tied housing).

Table 3 presents descriptive statistics for the variables in the inefficiency model. The estimated coefficients of this model were further analyzed with a simulation model to examine the influence of distance and parcel size on efficiency in greater detail. We followed the method used by Del Corral, Perez, and Roibas (2011). First, we constructed an average farm from the mean values of inputs (capital stock, land area, labor hours, and cost of materials and supplies) and efficiency determinants for 2000 through 2009. The production type of the average farm was fixed as conventional and the housing type as free-stall. Next, the expected TE score was calculated for the average farm using the estimated parameters of the stochastic production function. Furthermore, we varied the weighted average parcel distance and average parcel size in the simulation, *ceteris paribus*, from 50 percent to 200 percent of their means. As a result, the efficiency score of the average farm could be presented by parcel

Table 3. Descriptive Statistics of Inefficiency Model Variables

Variable Description	N	Sum	Mean	Std. Dev.
Average weighted parcel distance, meters/hectare	3,329	—	2,060	1,898
Average parcel size, hectares	3,329	—	2.5	1.21
Binary variable, production type, 1 = organic, 0 = conventional	—	228	0.07	—
Binary variable, housing system, 1 = loose, 0 = tied	—	753	0.23	—

distance and parcel size. NLOGIT software version 5 (Econometric Software, Inc., Plainview, New York) was used in the estimation.

Results

Production Frontier Function

The results of the stochastic production frontier model are presented in Table 4. The dependent variable is total output in milk liter-equivalents. All of the input variables in this model had a positive effect on production ($p < 0.001$). In the case of the Cobb-Douglas-type function, elasticities for the inputs could be obtained directly from the first-order coefficients. The input with the largest elasticity was materials (greater than 0.55) and the smallest was land area (less than 0.08). Neutral technical change captured by the time dummy variables was 1.4 percent per year on average. The regional dummy variables showed a slight advantage in production for region C1 relative to northern regions (C2–C2P and C3–C4) and the reference area (AB in southern Finland).

Technical Efficiency

Parcel size and parcel distance separately induced inefficiency but their interaction had no effect on it (Table 4). As expected, larger parcels and smaller distances decreased inefficiency. Parcel distance and its squared term were both significant determinants of inefficiency. Parcel size affected inefficiency but its squared term did not. The impact of organic production was not significant but free-stall housing decreased inefficiency significantly.

The overall average TE score was 79 percent with a standard deviation of 12 percent. During the research period, a small improvement in efficiency was detectable. The mean score was 78.3 percent in 2000 and 79.8 percent in 2009. Figure 1 illustrates milk production in each efficiency category at the beginning and end of the nine-year period and shows that production became more efficient.

The simulation results for the average farm are presented in Figure 2. The figure reveals a curved shape of the TE score on both dimensions. Disadvantages increase more rapidly as the parcel size falls below average. Moreover, larger parcels have greater TEs but the growth of TE is decreasing. For distance, the curvature is the opposite: the TE score increases more as the distance to the farm compound declines. Our variation of the parcel size by 50–200 percent caused variation of 0.72 to 0.85 in TE of the average farm. When the parcel distance was varied within the same 50–200 percent range, the TE varied between 0.84 and 0.71.

Discussion

This study investigated the effect of the size of parcels and their distance from the primary location on the efficiency of Finnish dairy farms. The effect of land fragmentation has been analyzed before by Del Corral, Perez, and Roibas (2011) and Wu, Liu, and Davis (2005) for the number of parcels and by Di Falco et al. (2010) for both distance and number of parcels. In those studies, land fragmentation had a significant negative effect on efficiency so our results align with those studies.

Table 4. Model Results

Variable Description		Coefficient	Std. Error	Probability $\lvert z\rvert > Z^*$	Significance
Deterministic Component of Stochastic Frontier Model					
β_0	Constant	3.00296	0.09086	0.000	***
β_c	ln *Capital*	0.16528	0.00592	0.000	***
β_a	ln *Land area*	0.07905	0.01073	0.000	***
β_l	ln *Labor*	0.10494	0.01037	0.000	***
β_m	ln *Materials*	0.55216	0.00816	0.000	***
Binary Variable for Year – Reference Year: 2000					
β_{t2}	2001	0.03134	0.01212	0.010	***
β_{t3}	2002	0.02756	0.01101	0.012	**
β_{t4}	2003	0.03160	0.01213	0.009	***
β_{t5}	2004	0.03946	0.01117	0.000	***
β_{t6}	2005	0.06222	0.01066	0.000	***
β_{t7}	2006	0.08691	0.01063	0.000	***
β_{t8}	2007	0.11238	0.01113	0.000	***
β_{t9}	2008	0.13013	0.01183	0.000	***
β_{t10}	2009	0.12728	0.01148	0.000	***
Binary Variable for Region – Reference Region: AB, Southern Finland					
β_{R2}	Region C1	0.04294	0.01654	0.009	***
β_{R3}	Regions C2–C2P	–0.01936	0.01328	0.145	
β_{R4}	Regions C3–C4	–0.07023	0.02143	0.001	***
Variance Parameters for Compound Error					
λ	Lambda[a] $= \sigma_u / \sigma_v$	2.74170	0.02585	0.000	***
σ_u	Sigma (u)	0.33952	0.00348	0.000	***
Coefficients in $u(i, t)$[b]					
δ_1	Average weighted parcel distance	0.08308	0.02650	0.002	***
δ_2	Average parcel size	–0.10571	0.03755	0.005	***
δ_3	0.5 × squared average weighted parcel distance	–0.01380	0.00272	0.000	***
δ_4	0.5 × squared average parcel size	0.01684	0.00925	0.069	*
δ_5	0.5 × average weighted parcel distance × average parcel size	0.00592	0.01331	0.657	
δ_{D1}	Binary variable, production type	0.13698	0.08234	0.096	*
δ_{D2}	Binary variable, housing system	–0.14308	0.05074	0.005	***
Log-likelihood		1,581.49			

[a] Weight of variation in technical inefficiency over variation in stochastic variable: σ = variation in the stochastic component of the error variable.
[b] $u(i,t) = [\exp\{\eta \times z(i,t)\}] \times |U(i)|$.
Note: Significance at 1 percent = ***; 5 percent = **; 10 percent level = *.

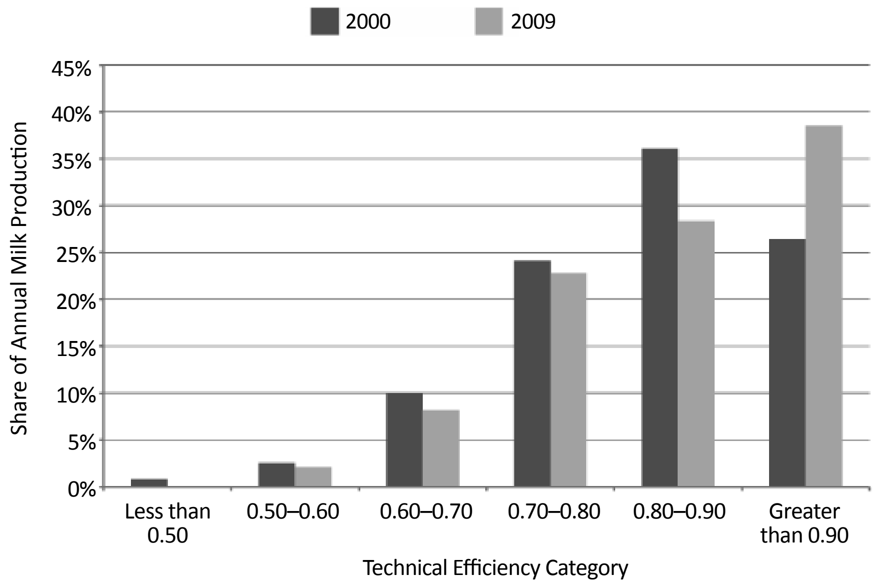

Figure 1. Milk Production by Technical Efficiency Categories in 2000 and 2009

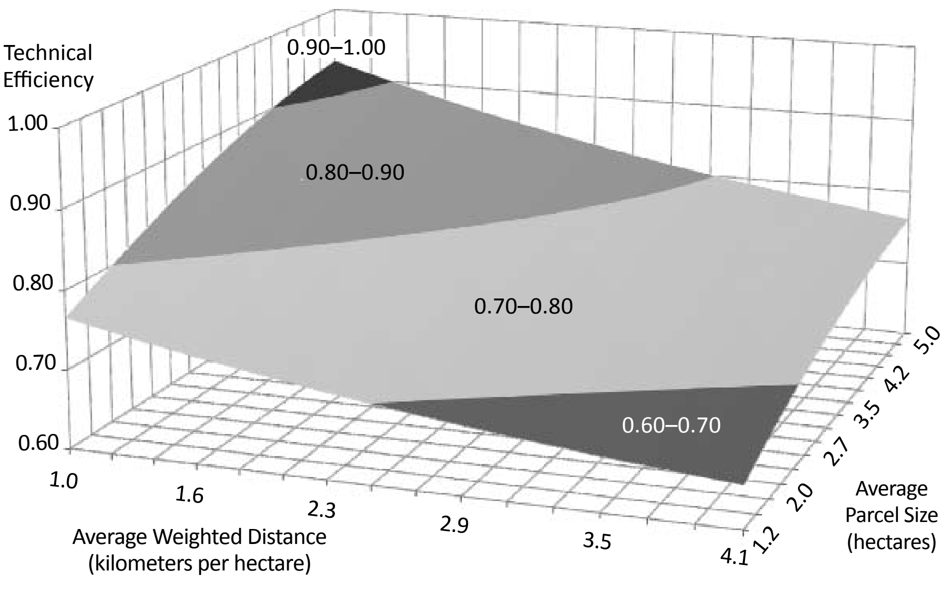

Figure 2. Expected Technical Efficiency for the Average Farm

In the empirical literature, there is growing concern about endogeneity in stochastic frontier analyses (Guan et al. 2009, Tran and Tsionas 2013). The endogeneity problem is caused by the presence of productive factors that affect the optimal choice of inputs for the farm that cannot be observed by the econometrician (Marschak and Andrews 1944). In stochastic frontier analyses, the Battese-Coelli (1995) estimator is widely used despite the inconsistent parameter estimates given in the presence of endogenous regressors (Kutlu 2010). Greene (2011) pointed out that accounting for endogeneity in a nonlinear model like the stochastic frontier analysis is difficult and Mutter et al. (2013) argued that there currently is no accepted approach for generating unbiased efficiency estimates with endogenous variables in a stochastic frontier analysis.

Mutter et al. (2013) also suggested that endogeneity and the biased inefficiency estimates to which it gives rise will be greater as the size of the variation between the operators increases. Our data set covered specialized dairy farms that mostly followed a single production strategy—producing their own roughage and spreading manure on disposable fields under environmental permits. Thus, unobservable differences in processes and resources and the bias associated with those differences are less of a concern.

Correlation between efficiency and input use is possible because determinants of the inefficiency term could affect the optimal choice of inputs. Costs associated with parcel distance originate from labor hours spent on the road and extra fuel plus potential costs related to logistics and maintenance of machinery. The labor input can be partly replaced by capital, such as with bigger tractors and larger loads. However, these possibilities are limited because traffic is controlled by law (maximum speed, load weights, and field road carrying capacities). Small parcel size also may limit the size of machinery and thus affect input use, requiring a greater reliance on labor than would be used otherwise. Moreover, production is less efficient on small parcels (Niroula and Thapa 2007) and the smallest parcels may be left fallow. However, we expect that the effects of parcel size are small in terms of the general farm input relationships.

In this study, observed determinants of TE cover factors related not only to parcel structure but also to the type of production and stalls. The binary variables for these two factors captured a large part of the sources of efficiency. Stall type relates to the size of the farm since only relatively small farms use tied stalls. Thus, any variation in efficiency due to unobserved factors was assumed to have a minor effect on input use. In summary, we followed the current literature and estimated the stochastic production frontier function under an assumption that the model did not suffer from endogeneity problems.

Our empirical analysis showed that larger distances and smaller parcels significantly decreased farm efficiency but that the disadvantage decreased elastically. Myyrä and Pietola (2002) estimated a shadow price for characteristics of land parcels based on parcel distance and size on Finnish farms. They found that small parcel sizes increased costs significantly but found no evidence that long distances represented a significant disadvantage. However, the overall size of farms in Finland has increased since collection of their data in 1998–1999 and seems to have crossed a threshold at which parcel distance begins to present a disadvantage. On the other hand, our data set included only dairy farms for which slurry spreading and roughage production represented a large part of the work done on fields and involved a large amount of transportation.

Myyrä and Pietola (2002) concluded that efforts to restructure parcels among neighboring farms to aggregate the parcels would generate greater returns despite the significant investment in cost and time required. Hiironen (2012) evaluated the profitability of consolidation of farm land with methods based on production cost estimates. According to that study, the distance to the primary farm compound in a division area could be reduced by half on average and field size would double. The consolidation would decrease the annual cultivation cost by 12 percent per hectare. In this study, we could not identify monetary benefits from restructuring parcels but found that consolidation would improve efficiency and thus also the economic performance of dairy farms.

The smoothly decreasing slope of the disadvantage of parcel distance can be explained by the fact that parcels located farther from the farm compound are typically reachable by roads that offer faster traveling speeds so the amount of time spent per kilometer is less than for field roads. This leads to the question of the maximum distance at which a field parcel should be purchased or leased. Our results do not provide an unambiguous answer but show that doubling average distance does not double the degree of disadvantage caused by distance.

Optimal parcel size was investigated by Myyrä and Pitkänen (2008). According to their results from a profit-maximization-problem method, areas larger than eight hectares have more than a 50 percent probability of being divided into two or more agricultural parcels. Similarly, according to our results, parcels greater than four hectares do not offer an appreciable advantage.

The dummy variables in the inefficiency model revealed weak evidence that organic production was less efficient than conventional production. This result is in line with a study by Oude Lansink, Pietola, and Bäckman (2002) that computed the TE of conventional and organic farms with a data envelopment analysis and discovered that organic farms use less productive technologies than conventional farms. The other dummy variable in our inefficiency model revealed that free-stall housing is more efficient than tied housing. This result is similar to several prior studies, such as Alvarez, Del Corral, and Tauer (2012).

The average TE score for the period was 79 percent, which suggests that it may be possible to increase milk production by using the same level of inputs and existing technologies more efficiently. The annual development of TE was 0.16 percent on average. Thus, development was positive regardless of unfavorable development in parcel structures and attendant negative effects on efficiency; the positive changes prevailed over the negative ones. Average efficiency increases not only because of improved efficiency by individual farms but because low-performing farms exit. This has been verified for the dairy sector by several productivity analyses (e.g., Myyrä 2009).

In theory, farms that exit release resources such as arable land that the more efficient farms that remain can use to expand. In reality, however, this does not occur very effectively because changes in land ownership are infrequent (Myyrä, Pouta, and Hänninen 2008). Increasing productivity and efficiency by expanding the size of a farm can conflict with the 2003 reform of CAP supports, which are mostly detached from production beginning in 2006. Direct area-based supports are capitalized into land leases (and, ultimately, into land prices) and cause inflexibility in the supply of agricultural land (e.g., Patton et al. 2008). The inflexibility in turn prevents developing farms from expanding and increases inefficiency through unfavorable parcel structures.

Conclusions

Fragmentation of agricultural land is a problem in many countries, including Finland. Because of property division resulting mainly from land divisions and settlement, ownership of agricultural land has become highly fragmented. In addition, the country's geography has resulted in small, often irregularly shaped parcels. Milk production has a twin relationship with arable farming since fields both produce feed for dairy cows and provide areas for spreading manure. Our results show that both parcel distance and parcel size explain the inefficiency of dairy farms to a significant degree. Therefore, efforts to improve the structure of agricultural parcels in Finland are justified. Tighter environmental restrictions, such as increases in slurry-spreading requirements, exacerbate these efficiency losses and could restrict farmers' ability to develop their productivity if the supply of land remains inflexible. To prevent such inflexibility and inefficiency, policymakers should not inhibit well-functioning land markets by imposing excessive regulations and policy measures that directly or indirectly affect markets.

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